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ABSTRACT

To investigate developmental differences in timesharing performance, 60 boys, 20 in each of three age groups (7-, 10- and 13-year-olds), performed an auditory matching task and a tracking task alone and concurrently, the latter under two sets of instructions. Decrements produced by concurrent performance were compared for the three age groups. When the timeshared tasks were presented as equally important, timesharing produced significantly greater proportional decrements in the tracking performance of the younger children. In all age groups, tracking task decrements were directly related to matching task difficulty. Subsequently, the children were instructed that one or the other of the tasks was more important and that they were to improve their performance on that task. All three age groups showed a significant improvement on the task emphasized by instructions. The relationship of the results to two models of information processing is discussed. (Author/BRT)

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Age Trends in Children's Timesharing Performance

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Running Head: Children's Timesharing

Abstract

To investigate developmental differences in timesharing performance, 60 boys, 20 in each of three age groups (7-,10- and 13-year-olds) performed an auditory matching task and a tracking task alone and concurrently, the latter under two sets of instructions. Decrements produced by concurrent performance were compared for the three age groups. When the timeshared tasks were presented as equally important, timesharing produced significantly greater proportional decrements in the tracking performance of the younger children and for all age groups tracking task decrements were directly related to matching task difficulty. Subsequently, the children were instructed that one or the other of the tasks was more important and that they were to improve their performance on that task. All three age groups showed a significant improvement on the task emphasized by instructions. The relationship of the results to two models of information processing is discussed.

That children improve their performance on a variety of activities with development is well known, but there are almost no data to indicate how concurrent performance of activities changes with development. The experiment reported here was designed to investigate developmental differences in how children timeshare when performing two concurrent tasks.

It's not unusual to perform two distinct activities at the same time, such as carrying on a conversation while walking or listening to music while reading. However, certain "biological bottlenecks" make it physically impossible to engage in certain activities concurrently; we cannot look in two different directions at once. Another limiting factor is less well understood but is related to the limits in the capacity for processing information.

Limited information processing capacity has been demonstrated in studies of timesharing with adult subjects. Generally, the concurrent performance of two tasks produces decrements in one or both of the tasks relative to levels of performance attained on the tasks alone (Welch, 1898; McLeod, 1973). This finding has provided one of the primary pieces of evidence which has led to the generation of several limited capacity models of information processing. These

models provide alternative descriptions of the nature and locus of the limits on man's ability to process information.

In one model, Kahneman (1973) states that all cognitive processes demand processing capacity. If a task can be performed with the allocation of less than the total capacity for mental effort, then the spare processing capacity can be allocated to the performance of a second task. Successful concurrent performance of a second task is interpreted within this model as indicating that adequate spare capacity has been allocated to the second task. Keele's (1973) model differs in that some but not all cognitive processes require space in a limited capacity mechanism. Decrements in timesharing appear when two mental operations simultaneously require the mechanism. The interpretations of developmental differences in timesharing performance and their implications for cognitive development provided by these two models will be discussed in a later section.

Performance decrements produced in a second task in timesharing are often a function of the difficulty of the primary task (Johnston, Greenberg, Fisher, & Martin, 1970; Posner & Bois, 1971: Kantowitz & Knight, 1974), where difficulty is defined by an error measure on the primary task in a baseline condition. The basic relationship between primary task difficulty and secondary task

decrements in timesharing has been replicated using a variety of primary tasks: same-different letter matching (Posner & Bois, 1971), memory tasks (McLeod, 1973), and a Fitts' tapping task at two levels of complexity (Kantowitz & Knight, 1974). Different secondary tasks have also been used, including tracking (McLeod, 1973), simple reaction time (Posner & Bois, 1971), and digit naming (Kantowitz & Knight, 1974). The research reported here was designed to provide information about the relationship between primary task difficulty and secondary task decrements in children's timesharing performance.

What is it that makes a particular task easy or difficult for a given individual? Mackworth (1970) has suggested that, with practice, a task no longer requires as much processing; it becomes easier. Because many daily activities are highly practiced for adults, they are considered easy. Experience tells us that while "easy" activities can be done at the same time, more difficult ones cannot. The same activities may be relatively more difficult for younger children, who have less practice on the component skills necessary for the performance of verbal and sensory motor tasks. If the same primary task is relatively more difficult for younger children, then this should be reflected in timesharing performance, with the younger children showing relatively larger decrements in the timeshared performance of the second task.

The use of the secondary task technique in interpreting timesharing performance is illustrated by the timesharing studies of Bahrick, Noble and Fitts (1954) and Bahrick and Shelly (1958). These studies were based on the notion that certain tasks become less susceptible to interference with practice. They investigated the possibility that performance on a secondary task could reveal effects of practice on a primary task after asymptotic levels of performance on the primary task had been reached. Results showed that timeshared performance on the secondary task later in practice of the primary task was superior to the timeshared performance on the second task earlier in practice. These studies demonstrated that secondary task performance can provide a sensitive measure of the degree of overlearning on the primary task not revealed by more conventional measures. The present study is not directly concerned with the effects of practice on performance. Here, the secondary task technique was used to look for developmental trends in the relationship between primary task difficulty and secondary task decrements in timesharing.

In his review of developmental differences in the temporal limits of information processing, Wickens (1974) tentatively concluded that in addition to developmental differences in performance attributable to non-processing factors such as practice, motivation, and incentive, there are irreducible developmental differences in

central information processing rates. Although the data are scarce in some areas, developmental differences in central processing appear in a variety of experimental settings, including tachistoscope recognition, visual search, stimulus familiarity, sequential effects, and choice reaction time. These data suggest that there may be developmental differences in central processing limitations in a task setting where multiple stimuli are presented and multiple responses are required. The research to be reported here is an initial investigation of the proposed developmental differences in central processing limitations.

In a study which systematically investigated the effects of verbal instructions about task priorities on the distribution of performance decrements in timesharing, Murdock (1965) found that giving instructions to adults to "concentrate primarily on" one or the other of the timeshared tasks produced distinct differences in the expected direction in the serial position curves of the timeshared memory tasks for the two instructional conditions. The timeshared tasks used were remembering a list of words and a card sorting task. The data were interpreted as evidence for subjects trading off the two tasks, that is, improving on the "concentrate primarily on" task while allowing larger decrements on the non-emphasized task. In a later study, Murdock (1969) cautioned

against his earlier interpretation and stated that the results may have been an aritifact of the particular tasks used. These studies offer some equivocal evidence that adults are able to modify their timeshared performance in the instructed direction, but there are no data on whether children can use such instructions. The present study investigated whether children were able to use verbal instructions about task priorities to modify their timeshared performance.

An auditory same-different matching task with two levels of difficulty served as the primary task. Level of difficulty was varied by changing the basis of the same-different judgments. It has been demonstrated that for adults, making judgments on the basis of a higher order rule is more difficult than making matches on the basis of physical identity (Posner & Mitchell, 1967; Posner & Bois, 1971). A one dimensional compensatory tracking task was used as the secondary task. To investigate developmental differences in the impact of verbal instructions on the distribution of decrements produced by timesharing, all children timeshared the auditory matching and tracking tasks under two sets of instructions.

Method

Subjects

The subjects were 60 boys, 20 each from the first-, fourth- and seventh grades. The mean ages for the three groups were 6 yrs. 11 mos., 10 yrs. 1 mo., and 13 yrs. 1 mo., respectively. All children were white, middle class and attended elementary school in Whitmore Lake, Michigan. All children had vision and hearing within the normal range. Two subjects from the youngest group were replaced, one for failure to perform one task and the other for failure to follow instructions. Each of the 20 subjects within an age group was randomly assigned to one of the two instructional conditions.

Apparatus and Materials

The experimental tasks selected for timesharing were a forced-paced auditory matching task and a compensatory one dimensional tracking task.

Auditory matching tasks. The stimuli for the matching tasks were three-, four- and five letter words from Thorndike and Lorge (1944) frequencies of 1-AA. Fifty-eight nouns were selected. Each noun could be classified as a member of one of four categories (12-16 words per category): animals, parts of the body, clothing, and food. The two difficulty levels of the

auditory matching task were generated by changing the basis of the matches. In the phonemic identity condition, judgments were based on phonemic identity of the words, "Are the two words in the pair the same word?". In category matching, judgments were based on category identity, "Are the two words the same kind of word?". For the phonemic condition, the stimulus pairs were constructed using words from all four categories. Half of the "different" pairs came from within a category and half from different categories. In the category condition the "different" pair words came from different categories and the "same" pair words came from within a category. The words in the "same" pairs were never phonemically identical. The order of the pairs was randomly determined in all lists, with the restriction that not more than three "same" or "different" pairs occurred in succession. Within a stimulus list no word appeared in more than three pairs. Each stimulus list contained 15 "same" and 15 "different" pairs.

In both types of auditory matching the stimulus pairs were presented at a rate of one pair every two seconds. Thirty pairs were given during each one minute trial. Six different stimulus lists were constructed for use in the phonemic condition and nine stimulus lists for the category condition so that no child heard the same stimulus list more than once. All the stimulus materials were recorded in the same female voice using a Sony Model 500 T tape recorder. The stimuli were presented binuarally through headphones.

A cassette recorder (Sony Model TC-80) was used to record all stimuli and responses during the presentation of the matching tasks. The timing of the verbal responses was recorded on the event recorder channel of a Bausch and Lomb Lab Recorder (Model VOM-5) that was connected through a voice operated relay to the microphone attached to the headphones worn by the child.

Compensatory Tracking Task. A Simplified Electronic Tracking Apparatus (SETA) of the type described by Gain and Fitts (1959a) was connected to a Tecktronix Type 503 cathode ray oscilloscope with a 15 cm display screen.

The SETA was housed in two cabinets: and experimenter's console and a subject's console. The experimenter's console generated the problem input. The problem generator was a potentiometer linked to a synchronous motor driven rotary cam. This cam caused the cam follower to move over an arc of 1.27 cm and this rotated the potentiometer 180 degrees. The irregularly shaped cam generated a sinusoidal voltage output which can be described by the following equation:

$$y = A(\sin \omega t + \sin 2\omega t)$$

$$\text{where } \omega = \frac{2\pi}{T}$$

$$T = 10 \text{ seconds}$$

Six complete cycles were presented in each one minute trial. The subject's error was calculated for each trial by an analog computer element also located in the experimenter's console. The analog element consisted of three K2X Philbrick operational amplifiers and their associated feedback components. The output of the component was the integration of the absolute value of the error voltage (integrated absolute error). Integrated absolute error (IAE) is thus calculated by continuously summing the absolute discrepancy between the problem input and the subject's output during each one minute trial:

$$IAE = \frac{1}{T}\int_0^T |X_d - X| \, dt.$$

The subject's console displayed the discrepancy between the problem input and the subject's output on a zero center voltmeter with a range of $\pm$ 12.5 volts located on the front panel. The subject's console was hidden from view by a plywood screen and the error was displayed on the cathode ray tube (CRT) of the oscilloscope as a dot which moved horizontally. In performing the tracking task the child manipulated the control knob with his preferred hand in order to keep the moving dot on the target dot in the center of the screen. Rotating the control knob 180 degrees was sufficient to compensate for maximum variations in

problem voltage. Control-display time delay was set at zero. Clockwise motion of the control resulted in movement of the dot on the CRT to the left. The subject's solution output was also recorded on the analog channel of a Bausch and Lomb Lab Recorder. The child was seated facing the CRT display that appeared in the 17.5 cm x 19.0 cm rectangular opening of a large plywood panel. The CRT display was approximately 45 cm from the subject and the height of the chair used was adjusted so that the display was near eye level for all subjects. The experimenter was seated to the left of the subject.

Procedure

The experiment was conducted during regular school hours in a trailer parked outside the school. Subjects were seen individually by the same female experimenter for one session about one hour in length. Within the session all children were given the same ordering of the tasks. A plan of the experimental session appears in Table 1.

Insert Table 1 about here

Subjects initially received ten tracking trials prior to the introduction of the auditory matching tasks. Trials one through seven were classified as practice trials, Trials 8-10 constituted

Block Tr_1, Trials 14-16 Block Tr_2, Trials 20-22 Block Tr_3, and Trials 26-28 Block Tr_4. Each tracking trial was one minute in duration and the intertrial interval was approximately 15 seconds. During this interval the subject was told his error score for the preceding trial. There were no regularly scheduled rest periods during this part of the session but if the child appeared tired or inattentive, or if his hand seemed to fatigue quickly, brief rests were given as necessary.

After the Tr_1 block, the phonemic matching (A_p) condition of the auditory task was introduced. First, three one minute trials were presented alone, then three A_p trials were given timeshared with tracking Trials 11-13 ($Tr+A_p$). Block Tr_2 followed the first timeshared block. Tracking alone blocks were interspersed in this manner in order to obtain a running baseline. Performance on timeshared blocks was always compared with the immediately previous alone blocks so that any practice effects operated in the direction of reducing differences between the alone and timeshared conditions. After a two minute rest interval, the category matching (A_c) condition was presented alone for three trials, followed by timesharing with tracking Trials 17-19 ($Tr+A_c$).

In both the timeshared blocks, $Tr+A_p$ and $Tr+A_c$, the tracking task and the auditory matching tasks were presented as equally important and the children were told to perform both tasks as well

as possible. Two minute rest intervals were given after the Tr_1, Tr_2, and Tr_3 blocks. During the rest intervals the subject was encouraged to leave his seat and move about. All other intervals between trial blocks were approximately thirty seconds long, and the intertrial intervals within all blocks were about ten seconds in length.

Following the Tr_3 block, instructions designed to alter timesharing performance were administered. At each age level the children were randomly assigned to one of the two instructional conditions. In one condition, the tracking task was emphasized, while in the other condition, the auditory matching task was emphasized. Either the tracking task or the auditory matching task was given special emphasis in three ways. First, it was designated as more important; second, the children were told to pay more attention to it; and third, they were told to improve their performance on the emphasized task in comparison with their performance on the previous timeshared $Tr+A_c$, equal-emphasis condition. After the administration of the instructions, the children performed another block of category matching timeshared with the tracking task, $Tr+A_c$, followed by the final tracking alone block, Tr_4.

Results

Compensatory Tracking Task

Because the baseline levels of performance on the tracking task alone were very different for the three age groups, performance decrements produced by timesharing were compared relative to each group's baseline level. A logarithmic transformation was done on the IAE scores for each subject and the transformed scores were used in all analyses of the tracking data. The ln transform eliminated the heterogeneity of variances that existed for the three age groups in the IAE data. By evaluating differences between the alone and timeshared conditions using the transformed lnIAE scores, statements were made about proportional decrements, rather than absolute decrements produced by timesharing: $\ln(Tr+A_p) - \ln(Tr) = \ln(Tr+A_p/Tr)$. This means, for example, that an increase in error score from 80 to 100 IAE units from the alone condition to the timeshared condition is equivalent to an increase from 20 to 25 IAE units, because the ratios of the alone and timeshared scores are the same in the two cases. Perfect performance corresponded to an IAE score of zero. The error score obtained by running the problem with no control response corresponded to a score of 5.65 lnIAE units.

When the three age groups were compared on the basis of their tracking performance in the alone conditions, the older subjects showed consistently smaller error scores throughout the session.

This is shown by the filled circles plotted in Figure 1, which presents the lnIAE scores for the three groups on Trials 2-22. For example, the mean lnIAE scores for the 7-, 10- and 13-year-olds on Trial 10 were approximately 4.2, 3.7, and 3.3, respectively. A one-way analysis of variance with age as the factor was done on the total lnIAE score for each of the four tracking alone blocks (Tr_1, Tr_2. Tr_3, Tr_4). The resulting F-values for all four analyses were significant at the $p<.001$ level. Pairwise comparisons on adjacent pairs of means (7-years, 10-years; and 10-years, 13-years) were also significant at the $p<.001$ level. Baseline tracking performance is clearly different for the three age groups through the session.

Insert Figure 1 about here

The major focus of the experiment was on the question of developmental differences in timesharing performance. To determine whether significantly greater proportional decrements existed in tracking performance as a consequence of timesharing for the younger children, tracking decrement scores in logarithm units were obtained for each subject. The total lnIAE score obtained on the immediately previous tracking alone block was subtracted from the total timeshared block lnIAE score for both types of the auditory matching task: $D_p = (Tr+A_p) - (Tr_1)$; $D_c = (Tr+A_c) - (Tr_2)$.

For phonemic matching, the tracking decrement scores, D_p, for the 7-, 10- and 13-year-olds were 1.25, .90, and .35, respectively. For category matching, corresponding tracking decrement scores, D_c, were 2.31, 1.73, and 1.30. Both auditory matching tasks produced larger proportional decrements in the tracking performance of the younger groups and for all groups category matching produced greater proportional decrements in tracking performance than phonemic matching.

A 2 x 3 analysis of variance for repeated measures was performed on the obtained D_p and D_c tracking decrement scores with type of match as the repeated measure and age as the second factor. The main effect of age was significant, ($F(2,57) = 7.98$; $p<.01$). Timesharing produced larger proportional decrements in the performance of younger children. The main effect of type of auditory match was also significant ($F(1,57) = 72.37$; $p < .001$), with category matching producing greater decrements than phonemic matching. The age x type of match interaction was almost nonexistent ($F(2,57) = .33$), indicating that the difference between the tracking decrements produced by category matching and phonemic matching was independent of the age of the children. Individual pairwise comparisons performed for each type of auditory matching task showed that for the D_p scores, the 10-years, 13-years pair ($t(20) = 2.07$; $p < .05$) was significant, while the 7-years, 10-years pairs was not. Corresponding comparisons

for the D_c scores indicated that the 7-years, 10-years pair ($t(20) = 2.01$; $p < .05$) was significant, while the 10-years, 13-years pair was not.

Auditory Matching Tasks

In analyzing the data from the auditory matching tasks, errors were defined to include both incorrect responses (i.e., saying "yes" when "no" was correct, or vice versa), and omissions. Predictably, the older children showed consistently smaller error scores on both types of auditory matching than the younger children. In the baseline alone conditions, the mean errors on the phonemic matching for the 7-, 10-, and 13-year-olds were 16.3, 5.3, and 3.9, respectively. For the category matching task, the scores were 44.8, 30.4, and 15.9, respectively. These scores are plotted for each 3-trial block in Figure 2 using the solid lines. An error score of 90 was the maximum possible.

Insert Figure 2 about here

Figure 2 shows that timesharing produced performance decrements in both types of auditory matching tasks for all age groups. The mean decrement scores for the 7-, 10-, and 13-year-olds on phonemic matching were 6.3, 6.2, and 3.1, respectively, and for category matching they were 9.4, 8.3, and 4.4. Two two-way analyses of

variance for repeated measures were done on the error scores with performance condition (alone or timeshared) and age as factors. The first analysis used the scores for the phonemic matching blocks, A_p and $Tr+A_p$, and the second the scores on the A_c and $Tr+A_c$ blocks. The main effect of performance condition was significant in both analyses: for phonemic matching, $F(1,57) = 21.40$, $p<.001$; and for category matching, $F(1,57 = 34.40$, $p<.001$. Timesharing produced decrements in the performance of both phonemic category matching tasks. The effect of age was significant in both analyses, A_p, $F(2,57) = 24.01$, $P<.001$; A_c, $F(2,57) = 31.04$, $p<.001$, reflecting the consistently larger error scores of the younger children. The performance condition x age interaction did not reach significance in either analysis; both F rations were less than 1.0, indicating that timesharing the tracking task did not produce decrements in the performance of the matching tasks which differed as a function of age.

As shown in Figure 2, the baseline levels of performance on auditory matching tasks alone differed for the three age groups (Box tests for homogeneity were not significant for the auditory match data). For this reason, the auditory matching data were also examined for developmental differences in proportional decrements produced by timesharing. Two one-way analyses of variance were performed using the obtained proportional decrement scores for phonemic matching $((Tr+A_p)-A_p/A_p)$ and category matching $((Tr+Ac)-A_c/A_c)$

tasks. The effect of age was not significant in either analysis, in agreement with the failure to note an interaction in the two-way analysis of the auditory matching error scores reported above. Timesharing does not produce proportional decrements in the performance of either of the auditory matching tasks which differ as a function of age.

Figure 2 also shows that more errors were made on category matching than phonemic matching for all age groups, and the difference between the error scores on the two types of matching tasks is greater for the younger children. Two 2 x 3 analyses of variance with type of matching task as the repeated measure and age as the second factor were done on the error data. The first analysis used the scores obtained on the matching tasks alone in the A_p and A_c blocks. The effect of type of match was significant ($F(1,57)=291.6$, $p<.001$, and so was the effect of age ($F(2,57)=45.10$, $p<.001$. The interaction was significant at the $p<.001$ level, ($F(2,57) = 15.4$; going from phonemic matching to category matching produced less change in the error scores of the older children. A corresponding analysis of the $Tr+A_p$ and $Tr+A_c$ timeshared scores showed very similar results. The effects of type of match were also examined using proportional difference scores (A_c-A_p/A_p) and $((Tr+A_c) - (Tr+A_p)/(Tr+A_p)$ rather than absolute scores, the age differences no longer appear. Two one-way analyses of variance using the proportional difference scores obtained in both the alone and timeshared conditions were performed. Neither F ratio approached

significance. Going from phonemic matching to category matching produces a greater absolute difference in the error scores for younger children, but there is no difference with age in the proportional change in error scores produced by going from phonemic matching to category matching.

Effects of Instructions on Timesharing

Half of the children at each age were randomly assigned to one of two instructional conditions. To determine that the two groups did not differ in their performance of either tracking or category matching prior to the administration of the differential instructions, two two-way analyses of variance with instructional condition and age as factors were done using the lnIAE tracking scores and the auditory matching scores for the Tr+A_c block prior to the administration of the instructions. In both analyses, the *F* ratios for instructional condition were less than 1.0.

Tracking-emphasis groups. When the tracking-emphasis Tr+A_c block scores were compared with the previous equal emphasis Tr+A_c block scores, the data show that all three age groups were able to improve their timeshared performance on the tracking task. The mean tracking and auditory matching scores for the tracking emphasis groups appear in Table 2.

A two-way repeated measures analysis of variance with instructional condition and age as factors was done using the lnIAE tracking scores. The two levels of the instructional factor were the equal emphasis condition of the previous $Tr+A_c$ block and the $Tr+A_c$ tracking-emphasized block. The main effects of instruction ($F(1,27) = 31.0$. $p<.001$) and age ($F(2,27) = 23.6$. $p<.001$) were significant, reflecting the better tracking performance of the older children in both blocks. The interaction was not significant ($F(2,27) = 1.79$), indicating that although the instructions were effective in producing performance changes in the desired direction, the impact of the instructions on performance was independent of age.

A corresponding analysis of the errors on the non-emphasized auditory matching task showed only a significant effect of age ($F(2,27) = 16.09$, $p<.001$), reflecting the generally better performance of the older subjects. Neither the effect of instruction nor the instruction x age interaction reached significance.

Auditory-emphasis groups. As shown in Table 2, the children in these groups were also able to use instructions to modify their timesharing performance in the instructed direction.

The data of the auditory-emphasis groups were subjected to the same analyses as those of the tracking-emphasis subjects. The results of the two-way repeated measures analysis of variance of the auditory matching errors with instructional condition and age as factors showed

both main effects were significant: instruction $F(1,27) = 6.71$, $p<.05$; and age $F(2,27) = 25.19$, $p<.001$. The interaction was significant for this group, ($F(2,27 = 4.54$, $p<.05$) and had the unexpected form noted above: the impact of the instructions was greatest for the youngest children.

The results of the corresponding analysis of the scores on the non-emphasized tracking task indicated that the effect of age was again significant ($F(2,27) = 14.2$, $p<.001$), reflecting the better performance of the older subjects. The interaction was also significant ($F(2,27) = 9.08$, $p<.01$) although the main effect for instruction was not. The tracking error scores of the two older groups showed slight increases when auditory matching was emphasized whereas the youngest children actually reduced their error scores on the tracking task.

Discussion

The results have shown that under timesharing conditions the auditory matching tasks produced less impact on the tracking task performance of older children. When the decrements obtained in tracking performance for the three age groups were compared proportional to their respective baselines, the younger groups showed significantly larger timesharing decrements. Because the baseline tracking error scores are greater for the younger subjects, this

means that the younger groups also showed greater absolute decrements. Predictably, the older children made significantly fewer errors on the auditory matching tasks when they were performed alone. This was true for both phonemic and category matching. The general relationship between primary task difficulty and secondary task decrements that has been noted in timesharing studies using the secondary task technique with adults (Johnston, et al. 1970; Kantowitz & Knight, 1974) appears when the age groups are compared: decreasing error scores with increasing age on the primary auditory matching tasks are accompanied by a corresponding decrease in proportional tracking decrements. This relationship was obtained for both phonemic and category matching tasks.

Developmental differences noted in the performance of the tracking and matching tasks in baseline alone conditions may be reflecting what Wickens (1974) has called non-processing factors: motivation, incentive and practice. The obtained developmental differences in proportional tracking decrements produced by timesharing suggest that, in addition, greater central channel processing limitations may exist for younger children, and that younger children are less able to divide their attention between two simultaneous tasks. This conclusion is in agreement with the results of research on developmental differences in rapid information processing tasks reported by Wickens (1974). To begin to determine the nature and locus of these central processing

differences, a more molecular analysis of timesharing performance, needs to be performed using temporal measures as well as error measures to look at performance within timesharing trials.

Category matching produced greater proportional decrements in tracking task performance than phonemic matching for all three age groups. The children in all three age groups also showed significantly larger error scores on category matching than phonemic matching, indicating that category matching was more difficult for all three groups. Once again, the direct relationship between primary task difficulty and secondary task decrements in timesharing previously found in timesharing studies with adults appears, this time in the data for each age group separately. For the children at each age level, making matches on the basis of a category rule (e.g., both are animals) was more difficult than matching on the basis of phonemic identity. This ordering is the same as has been obtained for rule versus identity matching uisng visually presented letters as stimuli. Posner and Mitchell's (1967) adult subjects produced longer reaction times for rule matching and these longer reaction times were used as evidence for rule matching requiring relatively more information processing than identity matching.

There are well documented changes with development in children's use of rules for the classification of stimulus materials (Flavell, 1963). With cognitive development, children become more able to use higher order abstract rules in classification tasks, while younger children show a tendency to rely on the use of physical dimensions as a basis of classification. In light of this evidence, it is surprising that the relative difference in difficulty between category matching and phonemic matching did not differ with age. That category matching was not relatively more difficult than phonemic matching for the 7-year-olds than the 13-year-olds is reflected in two aspects of the results: failure to note an age x type of match interaction in the time-shared tracking data and in the failure to note a main effect of age in the analysis of the proportional change auditory matching scores .

The limited capacity models of information processing of Kahneman (1973) and Keele (1973) have not addressed the general question of how information processing demands of tasks might differ for children at various levels of cognitive development, but these models can provide alternative interpretations of the obtained developmental differences in timesharing performance. The data of the present experiment do not provide support for one interpretation to the exclusion of the other.

1. The first interpretation is based on Kahneman's (1973) model. Man is conceptualized as having a limited general capacity for processing information. This general capacity is allocated to

processes and activities in a flexible manner. All mental processes, whether perceptual-motor or coding-transormational, require the allocation of limited capacity. If an activity can be performed with the allocation of less than the total capacity for mental effort, the spare capacity can be allocated to another task. Successful concurrent performance of a second activity is interpreted within this model as an indication that the individual has allocated spare capacity to the performance of the second task. Therefore, the addition of a secondary task can serve as a diagnostic tool for evaluating the demands for attentional capacity made by a primary activity. The finding that the younger children show larger proportional decrements in the secondary tracking task than the older children is interpreted within this framework as indicating that the younger children have relatively less spare capacity to devote to the performance of the secondary tracking task. The same auditory matching task demanded relatively more of the total capacity of the younger child.

2. This alternative is suggested by Keele's (1973) formulation, in which some but not all mental operations require space in a limited capacity mechanism. Decrements in timesharing appear when two mental operations simultaneously require the central mechanism. This model contrasts with Kahneman's in that not all operations are seen as requiring the allocation of capacity; some but not all mental operations require space in a limited capacity mechanism. Decrements in timesharing can appear when two mental operations simultaneously require

the mechanism. Operations that do not require the mechanism can proceed in parallel with other operations without interference. In general, processes of response organization and execution tend to make the greatest demands on central processing space, causing greater interference than perceptual processes. If children at different levels of cognitive development are using qualitatively different operations and strategies in performing the same timeshared tasks, then the performance differences in timesharing are reflecting different patterns of interference produced when different process combinations simultaneously require the limited capacity mechanism.

Subjects in all age groups in both instructional conditions were able to modify their timesharing performance in the instructed direction. Verbal instructions about task priorities proved to be a powerful factor in determining the locus of decrements in timesharing. For the auditory emphasis group, the effect of instructions was greatest for the youngest children. These seven-year-olds, who improved their auditory matching performance in the emphasized block over the preceding equal emphasis block, also improved their non-emphasized tracking performance. Unlike Murdock's (1965) adult subjects, the seven-year-olds did not trade off larger decrements in the non-emphasized task for improved performance on the other task; only the thirteen-year-olds in this instructional condition appeared to be trading off one task for the other in the manner of Murdock's adults. Because every subject probably has some set of

priorities about the relative importance of timeshared tasks even in the absence of specific verbal instructions, presumably based on environmental cues or expectancies, the present findings stress the methodological importance of explicitly conveying the task priorities to the subject so that obtained effects can be attributed with greater confidence to the factors being investigated.

Timesharing the auditory matching tasks with tracking has been shown to have an impact on tracking performance that decreases with increasing age. However, no such effect was found when the impact of tracking on auditory matching was examined. Focusing on the question of the existence of developmental trends in timesharing performance, this asymmetry in the data suggests that any general statements about age differences in timesharing performance, even for one particular primary task, must await the collection of data in situations that allow the pairing of that primary task with several secondary tasks. This is necessary in order to exclude the possibility that the results are specific to the particular tasks and combinations used, and to ascertain whether it is useful to assume some general ability to timeshare that is independent of the effects attributable to particular task and modality combinations.

Even the youngest children were able to timeshare two complex tasks, each requireing considerable skill and attention. The results of the present study suggest that timesharing can provide

important information about age differences in task performance not revealed by the more conventional measures of performance on the task alone. In their everyday experience, children often do two things at once, and the study of this phenomenon needs to be pursued. Further, although timesharing is a method with many methodological pitfalls, its careful application can also yield new information about the nature and locus of developmental differences in information processing.

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Footnote

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Table 1

Plan of experimental session

Performance Condition and Block Number	Task		
	Tracking		Auditory Matching
1 Alone (Tr)	Practice		
2 Alone (Tr)	Practice		
3 Alone (Tr)	Tr_1		
4 Alone (A_w)			A_w - Phonemic Matching
5 Timeshared	Tr	+	A_w
6 Alone (tr)	Tr_2		
7 Alone (A_c)			A_c - Category Matching
8 Timeshared	Tr	+	A_c
9 Alone (Tr)	Tr_3		
----------	Instructions	----------	
10 Timeshared	Tr	+	A_c
11 Alone (Tr)	Tr_4		

Table 2

Effects of Instructions on Timesharing. Mean lnIAE Scores and Auditory Matching Errors for Tracking Emphasis and Auditory Emphasis Groups*

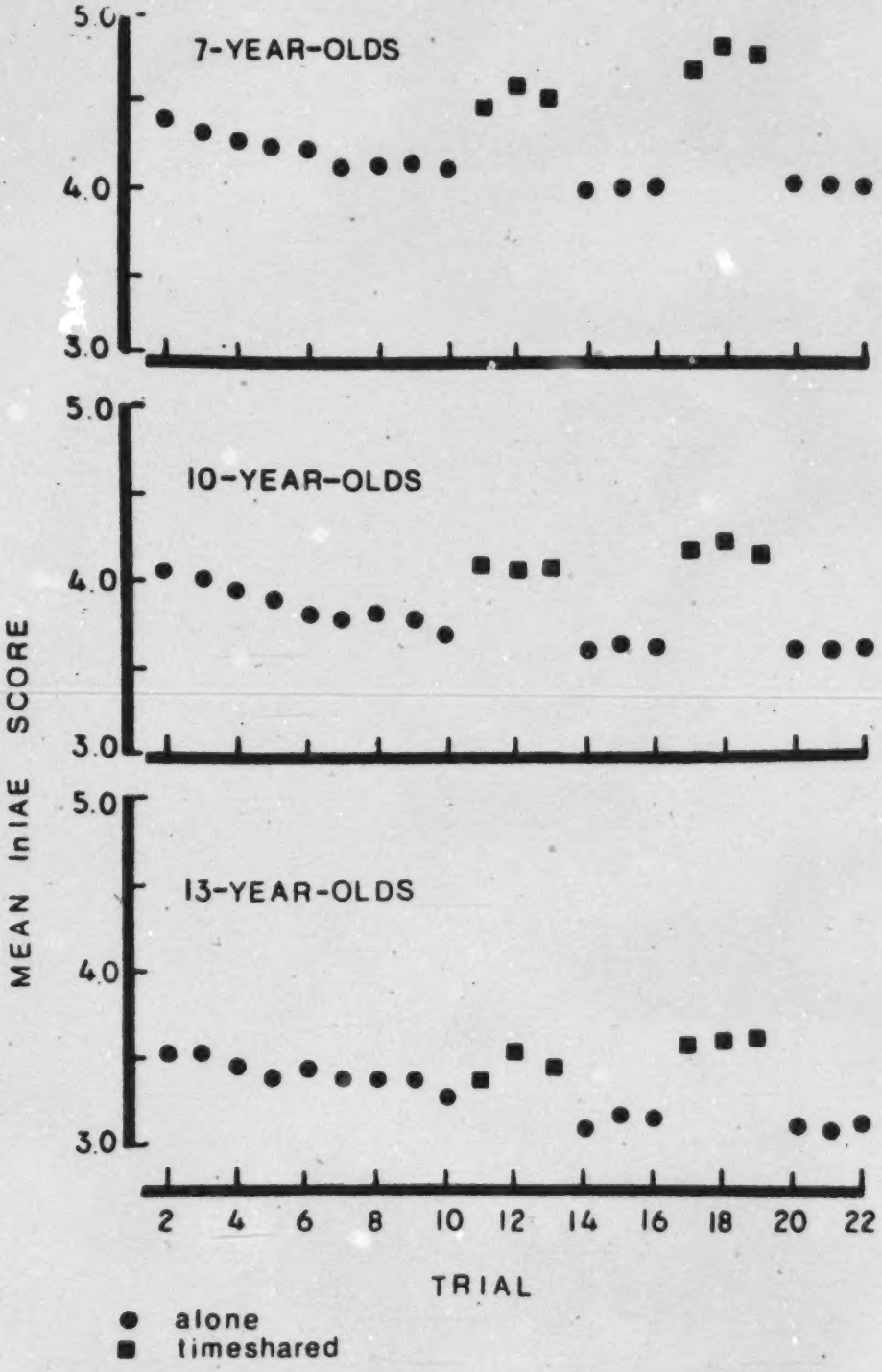
Age Group	Instructional Condition			
	Tracking Emphasis		Auditory Matching Emphasis	
	Block		Block	
	Equal Emphasis	Tracking Emphasis	Equal Emphasis	Auditory Matching Emphasis
7-year-olds				
lnIAE Score	4.97	4.83	(4.82)	(4.65)
Auditory Matching Errors	(52.0)	(53.0)	56.2	47.9
10-year-olds				
lnIAE Score	4.30	3.99	(4.28)	(4.44)
Auditory Matching Errors	(39.2)	(36.5)	37.8	38.6
13-year-olds				
lnIAE Score	3.62	3.30	(3.73)	(3.98)
Auditory Matching Errors	(22.7)	(24.5)	17.9	16.5

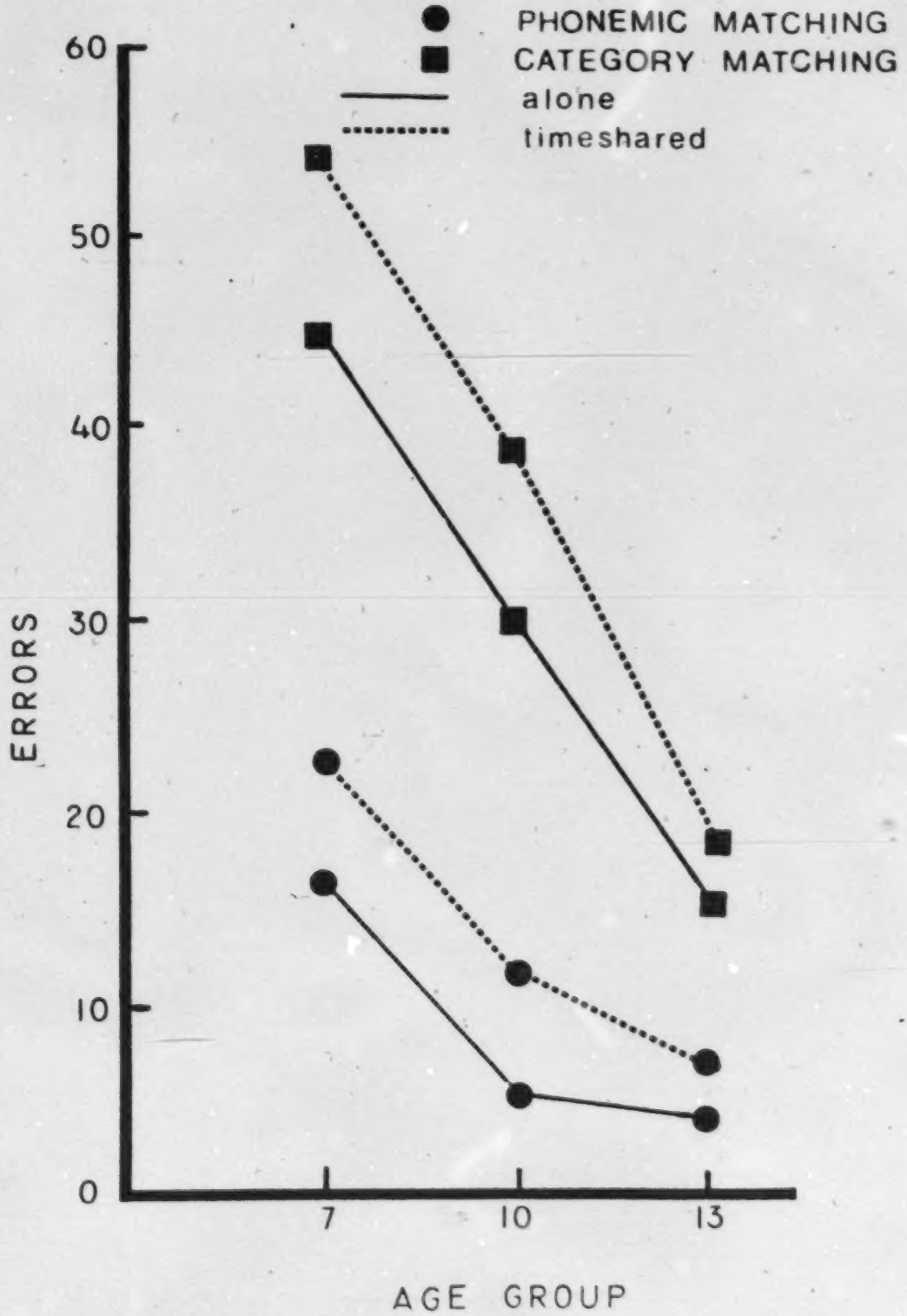
*Non Emphasized Task Scores in Parentheses.

Figure Captions

Figure 1. Mean tracking score in lnIAE units for Trials 2-22.

Figure 2. Auditory matching errors as a function of age group.


7-YEAR-OLDS
10-YEAR-OLDS
13-YEAR-OLDS
5.0
4.0
3.0
MEAN lnIAE SCORE
2 4 6 8 10 12 14 16 18 20 22
TRIAL
alone
timeshared


PHONEMIC MATCHING
CATEGORY MATCHING
alone
timeshared
60
50
40
30
20
10
0
ERRORS
7
10
13
AGE GROUP